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Decision support system for city logistics: literature review, and guidelines for an ex-ante model

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Abstract

The world is inexorably becoming urban. Since 2008, urban population is higher than the rural population. Therefore, cities are increasingly important systems for contemporary society. Phenomena such as urbanization and globalization have contributed to make urban centers more and more complex. One of the most important aspects is urban freight transportation, which is affected also by the spatial distribution of activities and residences. It follows that role of decision-makers is increasingly difficult due to limited economic and space resources that concern the urban areas. Besides, recent trends promoted by European Commission in the field of sustainable development require a profound reflections concerning the choice of transportation policies, and design of infrastructures. On the path towards to cities sustainability, local authorities have to make important decisions related to urban freight distribution.

In this complex framework, the present paper describes the first phase of a two-year research project called "SIPLUS - Systems for Sustainable Urban Planning of Logistics". The goal of SIPLUS is "development an ex-ante model for evaluation of interventions and investments in urban goods distribution, in favor of the municipalities". It is a decision support system for authorities and decision-makers. At the end of the project, there will be a pilot actions with the application of proposed models in at least one European city.

This paper describes the first results, which mainly concern literature review, state of the art, analysis of European best practices in city logistics, and the general framework of proposed model.

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1. Introduction

Nomenclature

BPA	Best Practices Analysis
CL	City Logistics
DSS	Decision Support System
FQP	Freight Quality Partnerships
LEZ	Low Emission Zones
KPI	Key Performance Index
SD	Sustainable Development
SP	Stated Preferences
TE	Transportation Externalities
UFD	Urban Freight Distribution
ULP	Urban Logistic Plan
UCC	Urban Consolidation Centers
WTA	Willingness To Accept
WTP	Willingness To Pay

Nowadays, there is growing interest in the concepts of sustainable development and sustainable transportation. Black (2010) argues that sustainability reflects one of the most fundamental human desires: to create a better future world. The concept of sustainable development has greatly evolved in last decades: United Nations Conference on the Human Environment, Stockholm, 1972; United Nations Conference on the Human Environment, Rio de Janeiro, 1989; Maastricht Treaty, 1992; Aalborg Charter, 1994; Amsterdam Treaty, 1997; Kyoto Protocol, 1997, etc..

The most common (and controversial) definition of sustainable development is defined by Brundtland Commission (1987): "it meets the needs of the present without compromising the ability of future generations to meet their own needs". According to E.C.M.T. (2004), it follows that a sustainable transport system is accessible, safe, environmentally-friendly and affordable. Studies developed by ISPRA (2009) show that more than 50% of worldwide population lives in urban areas, while in Europe this share increases and reaches the 75%. The urban mobility assumes a key-role in the promotion of sustainable urban development. In fact, urban areas consume about 70% of energy and produce about 80% of G.H.G. (ISPRA, 2009). Urban mobility accounts for 32% of energy consumption, and for 40% of all CO₂ emissions of road transport, and up to 70% of other pollutants from transport. The congestion of urban roads is responsible not only for the increase in environmental pollution and energy consumption, but also for increasing the length of trips, with a consequence increase of delay time. Every year the European economy loses approximately about 1% of GDP with this phenomenon.

Every transportation system generates externalities. However, it is in urban areas that these externalities are more significant. European Commission (2007, and 2008) has identified and classified several external costs of transport. European Commission proposes to support towns and cities with a number of actions to make urban transportation systems accessible to all. Regarding freight, in particular, the following three suggestions stand out: the use of alternative modes of transportation (inland waterways and railways); a central computer network to cluster freight and avoid empty rides; and widening delivery-time windows.

The present study is directly related to the following concepts: Sustainable Development (S.D.); Transport Externalities (T.E.); Urban Freight Distribution (U.F.D.); City Logistics (C.L.).

The main aim is to define a tool with which to identify, in advance, possible sustainable interventions/policies for the improvement of city logistics, in compliance with environmental constraints (min. externalities), economic constraints (maximum investment expected by decision-maker), and guaranteeing goods supply to retailers, and end-users.

The paper is structured in following phases: literature reviews; measures classifications, and best practices analysis in city logistics (B.P.A.); proposed methodology; conclusions, and possible future developments.

2. Literature review

Literature review has involved the following topics: sustainable urban mobility (transport-territory interactions study, regulatory framework, criticality, main indexes, solutions, etc.); urban freight models (urban logistics chain; the actors; regulatory framework; impacts; policies and measures; etc.); externalities estimation methods (methodological approach; projects; etc.); ex-ante models in city logistics (tools; applications; case studies; etc.). In this phase, were analysed several books, scientific papers, publications, E.C. directives, websites, etc.. Literature analysis was completed in December 2013. In this section we describe the primary results of literature review. The part relating to the key measures, and case studies, is defined in the next section.

In order to analyse the impacts generated by a transportation system, it is essential to know urban spatial distribution, and the interactions between this spatial distribution and transportation network. To analyse the urban system, and its sub-systems, have been studied in detail the interactions between urban context, and mobility, in order to better understand the mutual relationships between activity system, residential system, transport system, etc.. To achieve a complete and efficient urban model, it is required a detailed knowledge of the "city system", with its components, actors, interactions, classifications, evolutions over time, etc.. In particular, we highlight some aspects deemed important for the present study: mutual interactions between land-use and transport system (Banister and Marshall, 2007; Wegener and Fürst, 1999); urban development models (Burgess, 1925; Hoyt, 1939); urban change processes (Wegener, 2004); classification of urban spatial structures (Rodrigue et al., 2006). A systematic and integrated approach, which aims to solve a problem of urban mobility, must consider these aspects. In literature there are numerous models for the study of the interactions between transport and territory, divided into three categories: technical approaches (i.e.: Lowry, 1964; Wegener and Fürst, 1999); economic approaches (i.e.: Alonso, 1960 and 1964); social approaches (i.e.: Hägerstrand, 1970).

Urban goods distribution is conditioned, therefore, by spatial distribution of activities, residences, services, etc.. It produces significant impacts to urban mobility. According to some statistics defined by Nuzzolo (2013), in Milan and Rome the 68% of the commercial vehicles has a load factor of less than 0.25. Eurostat statistics (2013) show that in Europe urban distribution of goods generates impacts for 56% of total emissions of particulate, and for 28% of CO₂ emissions. Highway Capacity Manual (2010) defines that commercial vehicles have a higher rate of use of road infrastructure, compared to cars. Goods distribution is one of the main components of urban mobility. A thorough description of the city logistics taxonomy was discussed by Benjelloun et al. (2010), while other authors, such Crainic et al. (2004), have analyzed freight transportation systems in congested areas.

Minimize the impact of mobility is one of the main objectives of municipalities and decision-makers. In this context, freight transport has gained a more important role in urban planning, first in large cities; however, the medium and small cities also need to address the problem in the decision making process (Lindholm, 2012). Recently, local governments have demonstrated a growing interest in city logistics and transportation planning processes (Lindholm, 2010). A literature review on the urban freight transport from a local authority perspective has been described by Lindholm (2013).

In general, the assessment of logistics policies is addressed by Hosoya et al. (2003) who developed a study for Tokyo. Starting from S.P. surveys, they evaluated a number of logistics policies: bans on large trucks, road pricing, and construction of logistic centers. They present some models for evaluating firms' behavior and interaction when the policies are implemented. Anderson et al. (2005) provide an ex-ante assessment of regulation measures in UK cities, including time windows and charging. Regulations based on time windows was addressed in Quak and de Koster (2006), who reviewed the state of practice in Dutch cities and provided an assessment of possible changes to current policy.

Analysis of stakeholder behavior related to some measures has been proposed by Taniguchi and Tamagada (2005), who have developed a methodology for evaluating city logistics measures considering the behavior of several stakeholders associated with urban freight transport. Considering five stakeholders, administrators, residents, shippers, freight carriers, and urban expressway operators, they performed a simulation on a test road network where a truck ban and tolling of urban expressways were introduced. The problem was formulated as an optimization problem. Models are used to estimate a wide range of impacts including social, economic, environmental, and financial. For the estimation of social impacts, resulting from reduction of traffic congestion and crashes, and economic impacts, due to changes in fixed and operation costs, some proposed formulations provide a combination of input-output approach with the multi-step modelling process (Taniguchi et al., 2001); Taylor and Button (1999)

give an application example.

Environmental impact models predict air pollution (NO_x, CO₂, etc.) and noise levels. For a state of the art on this topic, see Kroon et al. (1991). Some applications are reported in Taniguchi and van der Heijden (2000) and Ma (1999). The economic-financial impacts usually refer to techniques based on cost-benefit analysis (Ooishi and Taniguchi, 1999). For recent developments in urban freight studies, see Taniguchi and Thompson (2008). Many of these studies consider only some aspects of problems related to implementing urban freight transport policies (e.g., demand estimation and impact evaluation). Some of them use S.P. surveys to catch the stakeholder's behavior, but the possible advantages of this type of survey are obtained at the price of introducing some distortion in the results and in the models calibrated. Distortions stem from the possible differences between stated and real choice behavior (Hensher et al., 1988).

State of the art relating the external costs evaluation has been carried out for single externalities, considering several documents, mainly E.C. directives (Environment Action Programs, White Paper, Green Paper, etc.). For each transportation externalities, has been identified the main methodological approach (top-down, bottom-up, W.T.P., W.T.A., etc.), the input, and the output. The most used tools are listed in the following table:

Table 1. Some studies for external costs estimation.

	Accidents	Pollutants	G.H.G.	Noise	Congestion
GRACE (2006)	x	x	x	x	x
HEATCO (2005)	x	x		x	x
CAFE-CBA (2005)		x			
UNITE (2002)	x	x	x	x	x
INFRAS (2007)	x	x	x	x	x

The most comprehensive tools are UNITE (2002), GRACE (2006), and INFRAS (2007). Detailed statistics relating transportation externalities in EU-27 are contained in "External Costs of Transportation in Europe" (INFRAS, 2011).

Literature analysis of ex-ante models in city logistic showed a certain lack of detailed studies characterized by integrated approaches. However, two approaches have been identified and analysed. However, two approaches have been identified and analysed. The first (Russo and Comi, 2011a) proposes a classification of the measures, and a simplified model; the second (Filippi et al., 2010) proposes a more complex approach. Both papers provide a detailed classification of the measures, and a modeling on several levels. Nevertheless, there are few studies that consider all factors and actors so far set out, with an integrated and coordinated methodology. Urban goods transport implies, in fact, a complex system, including a transport system, infrastructures and urban planning, and the logistic strategies of shippers (including forwarding and supply chain activities, land use and the community environment).

Many approaches have been proposed in literature, with different purposes (diagnosis, forecasting, simulation, etc.), models developed (top-down, bottom-up, mixed, etc.), applications (Groningen, Tokyo, Rome, etc.), and commercial tools (VISEVA, FRETURB, etc.). Therefore, the main references are Boerkamps and van Binsbergen (1999), Wisetjindawat and Sano (2003), Filippi et al. (2010), Muñuzuri et al. (2010). A general overview of these approaches is available in Gonzalez-Feliu & Routhier (2012).

In summary, literature analysis has shown a lack of integrated studies that analyze the urban systems, from different points of view. Ex-ante models identified are useful to test the effectiveness of a measure chosen, but only in rare cases these tools represent a real support to decision-makers in making such choice.

3. City logistics measure classification, and best practices analysis

This section is divided into three parts:

- Literature measures classifications;
- Proposed measures classifications;
- B.P.A.: methodology and results.

3.1 Literature measures classifications

Main European studies that defined a classification for C.L. measures implemented in urban areas are COST 321 (1998), City Ports (2005), Muñuzuri et al. (2005), BESTUFS (2007), van Duin and Quak (2007), Russo and Comi (2011b), and C-LIEGE (2013). Three of these are described below.

Muñuzuri et al. (2005) propose to classify measures depending on the actors which should be responsible for the implementation, but afterward they focus on measures implementable by the local administrator and classify them according to five fields of applications:

- solutions related to public infrastructure include transfer points useful to improve the load factor of vehicles driving within the city or the adaptation of train and underground system for deliveries;
- solutions related to land-use management refer to measures related to reserve areas for loading and unloading operations;
- solutions related to access conditions consider measures related to spatial and time restrictions;
- solutions related to traffic management are measures that could be introduced to improve the freight flows that affect actors in different ways, the implementation of intelligent transportation system (ITS) solutions, and cooperation schemes;
- solutions related to enforcement and promotion, measures that work together with others to promote without imposing.

Van Duin and Quak (2007) classify according to three main area of interest for city logistics without stressing the expected goals:

- flow improvements, including cooperation among companies, consolidation centers, transportation reorganization, and routing improvements;
- hardware, including infrastructure, parking, and unloading facilities;
- policy, including licensing and regulation.

Russo and Comi (2011b) have provided a very comprehensive classification, which consists of four categories.

- Measures related to “material infrastructure” are: linear, if they refer to links of the urban/metropolitan transportation network (e.g., use of an urban transportation sub-network only for freight vehicles); surface (or nodal), if they refer to areas that can be reserved for freight operations (e.g., areas for loading and unloading operations and logistic nodes to optimize freight distribution in metropolitan/urban areas like urban distribution centers).
- Measures related to “immaterial infrastructure” include not only consolidated ones (e.g., research, learning, and training), but also telematics or intelligent transportation system.
- Measures related to “equipment” include: measures on loading units, which refer to the introduction of new standards for loading units to optimize handling and transportation by new low-emission vehicles; measures on transportation units, which refer to characteristics of transportation units (e.g., reduction in truck emissions and use of electric vehicles, methane vehicles, metropolitan railways, or trams).
- Measures related to “governance” of the traffic network include traffic regulations such as time window access, heavy vehicle network, and road pricing.

3.2 Proposed measures classification

The aim of SIPLUS Project is to define the guidelines for a D.S.S. in favor of municipalities, in the field of city logistics. This tool must be flexible and replicable in order to adapt to cities with different spatial distribution. Therefore, we opted for a more detailed classification than those listed above. It is required for three reasons: 1. to better distinguish all possible initiatives of city logistics, highlighting positive and negative factors, 2. to identify the

potential benefits in terms of external costs, for each one measure; 3. to define, in the ex-ante assessment model, a more accurate choice framework (set of measures, fig. 2b).

In this paper we defined two classifications: disaggregated (with 36 kinds of measures), and aggregated (with 6 main categories of measures).

The *disaggregated classification* includes: 1. access restrictions, regulations, and control; 2. optimization of routes (routing and scheduling); 3. environmental zones (L.E.Z.); 4. U.L.P.; 5. F.Q.P.; 6. fleet management; 7. driver's behavior and driver support (eco-driving, driver training, and on-board computers); 8. virtuous behavior incentives; 9. campaigns for better use of vehicles and infrastructures; 10. innovative financing and business models; 11. bays: design and advanced book; 12. Van-sharing service; 13. Mobility credits scheme; 14. alternative delivery systems; 15. freight exchange (to reduction empty returns); 16. demand management; 17. U.C.C.; 18. distribution micro-platforms in the inner city; 19. use of environmentally friendly vehicles, alternative fuel, and clean vehicle; 20. modal shift, and multimodal transport; 21. IT logistic tools; 22. ITS solutions; 23. measures to tackle freight noise; 24. night deliveries; 25. road charging, and road pricing; 26. multi-users lanes and park, and lorry lanes; 27. land-use transport plans; 28. load factor maximization; 29. time windows/slots restrictions/booking; 30. mobility master plans; 31. financial support to fleet conversion; 32. online routing tools; 33. information; 34. incentives for good behavior; 35. waste cycle; 36. perishable goods logistics. It is a very detailed classification, but rarely a project relates to only one of the above mentioned measures. One of the main difficulties of the study was to identify, for each project, the primary measure implemented. Nevertheless, statistical analysis of the implemented measures considers both primary measure, and secondary measures.

The *aggregated classification* has been proposed in order to show the results of the analysis regarding the geographical areas (B.P.A.). It consists of: 1. areas (restrictions, pricing, L.E.Z., etc.); 2. support to operators (routing, parking, bays, information, etc.); 3. governance (F.Q.P., planning, incentives, etc.); 4. vehicle and fleet (clean vehicle, fleet management, etc.); 5. infrastructures (U.C.C., transit point, etc.); 6. innovative systems (I.T.S., etc.).

To summarize: disaggregated classification is important for the model proposed in next chapter; the aggregated classification is useful for showing the results of B.P.A., especially in the comparative study between the measures used, and geographical areas in Europe.

3.3 B.P.A.: methodology and results

B.P.A. has concerned 279 measures in 159 worldwide cities. The selected sample is relative to twenty major projects in urban logistics in last two decades. These projects represents the main sources of the data-base created, among which are cited: BESTUFS (www.bestufs.net); MEROPE (INTERREG IIIB MEDOCC); C-LIEGE (www.c-liege.eu); CITY-PORTS; START; SUGAR (www.sugarlogistics.eu); CIVITAS (www.civitas.eu); SmartSet (www.smartset-project.eu); FREILOT (www.freilot.eu); SMARTFREIGHT (www.smartfreight.info); FIDEUS; BESTFACT (www.bestfact.net).

For each C.L. initiative were collected the following information: project identification; main goals; short description; category of measure (according to disaggregated classifications); city and nation; year of implementation; developers (public and/or private); current status of the project; main results; replicability, or not.

Most important is geographical classification in 18 areas: Iberian Peninsula (Spain and Portugal), France, Italy, Adriatic Area (Slovenia, Croatia, Albania, Bosnia and Herzegovina, and Montenegro), Balkan Area (Serbia and Bulgaria), Eastern Europe (Poland, Slovakia, Czech Republic, Hungary, Romania, Moldova), Germany, Scandinavia (Finland, Sweden, Norway, and Denmark), Ex-Russia (Russia, Estonia, Lithuania, Latvia, Belarus, Ukraine, etc.), United Kingdom (England, Wales, Ireland, Northern Ireland, Scotland), Benelux (Netherlands, Belgium, Luxembourg), Central Europe (Switzerland and Austria), Southern Mediterranean (Greece, Turkey, Cyprus, Malta); North America (USA and Canada), South America, and Latin America; Africa, Asia, Australia and New Zealand. The considered sample is: 91% Europe, 9% other countries. Despite cities as Tokyo, Los Angeles, Yokohama, Melbourne, Durban, etc., represents very interesting case studies, this analysis has considered mainly the European areas. Subsequent analyzes relate only to these areas.

. The main results are:

- the primary measure more adopted is access restrictions (10%), followed by use of "clean vehicles" (9%), and U.C.C. (9%). Significant percentages also for pricing policies, and F.Q.P.;

- areas with the highest number of case studies is United Kingdom (15.77%), France (11.47%), Italy (13.26%), Benelux (10.04%), and so on (fig. 1a);
- 80% of analysed cases are concluded, and the developers are public-private partnerships in 90% of cases;
- In cities with high populations are implemented predominantly restrictive measures;
- The replicability is closely related to objective urban parameters, however, has been defined a scale of replicability: high (Governance), medium (support to operators, vehicle and fleet, innovative systems), low (areas, infrastructures).

The areas/measures analysis (fig. 1b) shows that:

- Scandinavian area often uses the process of external costs internalization through pricing policies (areas);
- UK it has consolidated its tendency to adopt F.Q.P. measures;
- Use of U.C.C. is well developed in Central Europe (Germany, Austria, Switzerland), together with the modernization of the vehicle fleet, and the implementation of new patterns of urban distribution (electric vehicles, cargo-cycle, etc.).

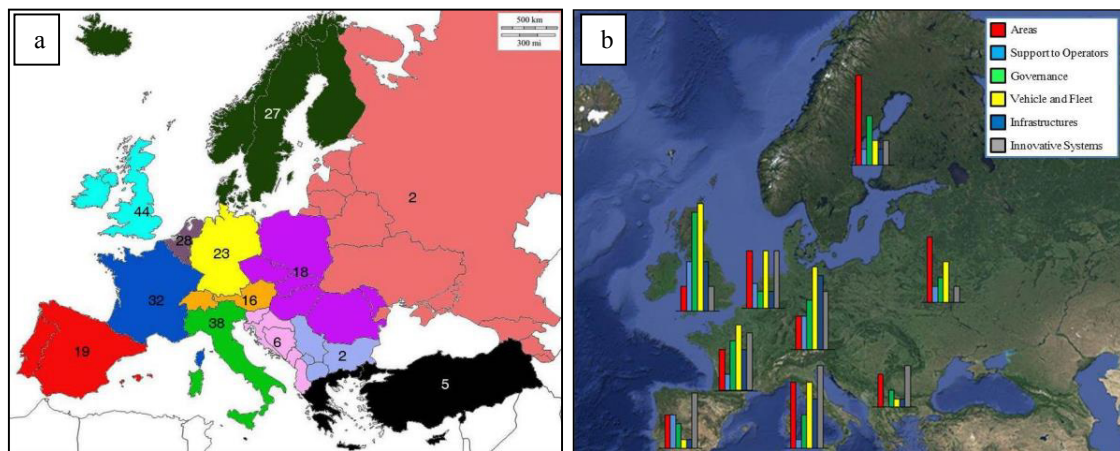


Fig. 1. (a) subdivision areas Europe, and number of case studies for each one area; (b) area/measures study (in according to aggregated classification)

In summary, best results are associated to long-term projects.

Finally, we note the need for integration of several actors involved in the process of project identification, and addressing of resources (economic, urban spaces, etc.), and the need to define projects that, at the end of the funding period, are self-sustaining.

4. The proposed methodology

Urban transportation system is a complex system in which freight is moved on the same transportation infrastructure on which passengers travel. The complete problem of city logistics, from the end-consumer to the producer, has been rarely addressed. In the analysis of urban freight transportation, two main freight movements are identified as follows: end-consumer movements: logistic movements.

Several actors are (directly or indirectly) involved in urban goods transportation. Starting from the classification proposed by Ruesch and Glucker (2001), we can identify the following three actor classes:

- End-consumers include Inhabitants (residents, businessmen, or employees), whose main interest is minimum hindrance caused by goods transportation; Visitors or the shopping public, whose main concern

is minimum hindrance caused by goods transportation, a variety of the latest products in the shops, and low price of products.

- Logistics and transportation operators include the shipper (wholesaler), whose main interest is delivery and pickup of goods at the lowest cost while meeting customer needs.
- Public administration includes; the local government, whose primary concern is an attractive city for inhabitants and visitors with an effective and efficient transportation operation; the national government, whose primary interest is to minimize external effects from transportation and maximize net economic benefits.

This paper describes the general architecture of proposed model, which involves the above mentioned actors. It regards two processes related to different scenarios: initial state (diagnosis); future state (forecast). The proposed methodology is divided into two phases: a general framework (fig. 2a), and an ex-ante assessment process (fig. 2b).

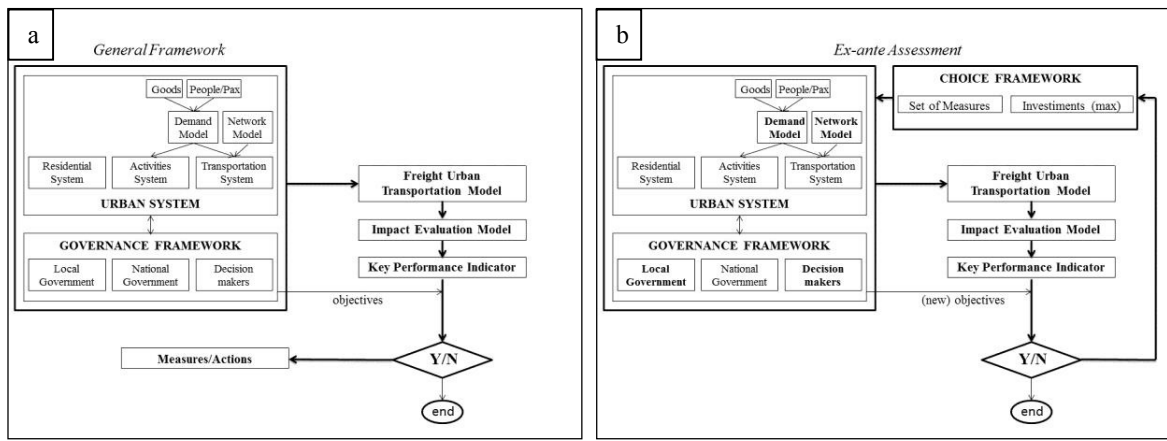


Fig. 2. (a) General framework of methodology proposed (initial state). (b) Ante assessment of methodology proposed

In this paper the model is analysed qualitatively, describing the elements that compose it, and the tools to use.

General framework consists in two main elements: urban system, and governance system. Urban system is composed by: activities system; residential system; transportation system. The governance system is made up of administrations and decision-makers, both local and national.

Through the modelling of freight transport system (Freight Urban Transportation Model), we evaluate the impacts of urban logistics, estimating some key factors. Several key factors and indexes were analysed (Betanzo-Quezada & Romero, 2010), selecting for this study transportation externalities. If these indexes show tolerable impacts, it means that the city should not adopt new C.L. measures. Otherwise, it is necessary to implement city logistics measures. General framework is, therefore, a diagnostic tool that allowing to define if a city should adopt new C.L. measures, or not, according to pre-defined objectives.

Diagnosis phase is a description of the current state, where the urban system is modelled and simulated using an appropriate tool (VISUM, MTCP, TRANUS, etc.), and the objectives are defined by the local government.

Ex-ante assessment model is a process to evaluate possible future scenarios, and select one of them. This model consists of the same systems of general framework, with the addition of a choice framework, that generates an iterative process. The choice framework is divided into: set of measures that can be implemented (1, n), and maximum investments. The latter, obviously limits the set of measurements that is characterized by disaggregated classification. The objectives can be re-fixed, even becoming more restrictive, due to investments.

Through an iterative process, the method allows to identify sustainable solutions, namely those that reach the goals, with an investment compatible with availability. The second phase allows to define, among these, the optimal solution, according to chosen indexes (K.P.I.).

The model described represents a possible solution to identify the best city logistic measure to be adopt in a city. It is a flexible and replicable model that will be implemented and tested in at least one European city.

5. Results, and future developments

Proposed model is based on a thorough literature analysis. This knowledge was important to achieving the contribution of this work represented by: 1. B.P.A. results; 2. definition of disaggregated classification; 3. Qualitative definition of ex-ante model architecture.

Measures choice varies widely in terms of geographic region (Fig. 1b). Some states prefer pricing measures (Norway), or access restrictions (Italy, Benelux). Other countries use initiatives in the field of governance (UK, Germany). Still others prefer measures related to vehicles and fleets (France). These information are very important to understand the trends in the field of city logistics.

Disaggregated classification is more detailed than other classifications identified in the literature.

The model, although qualitative, provides a good starting point for coping with the demands of municipalities: adopt an automated and effective tool, to identify the measures to implement, and to estimate the related benefits.

Future developments of the work are as follows: data collect; choice of tool to be used to implement the model; tool implementation; application of the defined framework to a case studies (pilot action in City of Genoa); tool calibration; application of defined framework to other case studies; improvement of the tool, considering non-standard conditions (different weather conditions, special events, etc.).

Ultimately, the proposed model is a scheme that integrates multiple aspects and actors of urban logistics, and which aims to optimize resources for municipalities, and realizing concrete projects on long-term.

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